Luka Leskovec

in collaboration with: R. Briceño and J. Dudek

ODU & JLab

On determining coupled-channel photoproduction amplitudes in finite-volume

shining a light on hadrons

9th Workshop of the APS Topical Group on Hadronic Physics

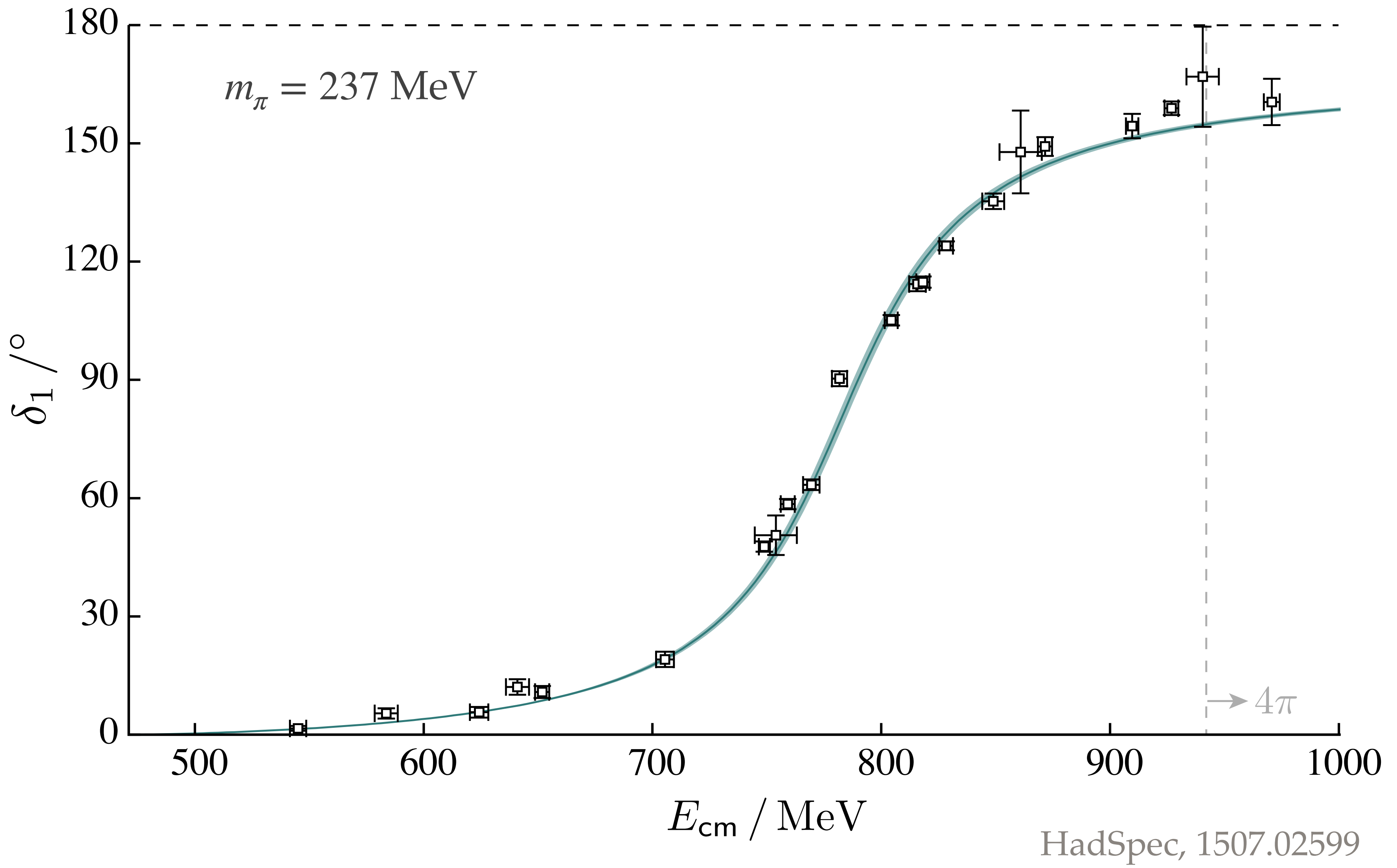
13–16 April 2021

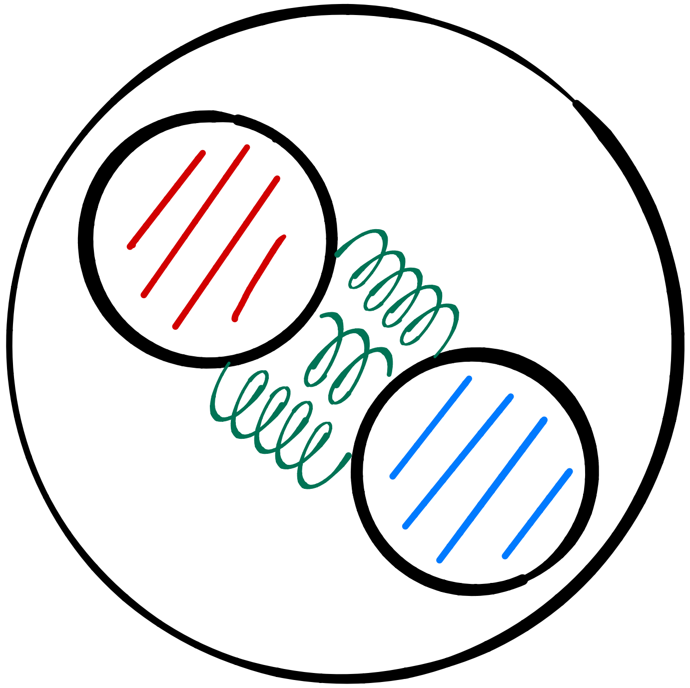
Virtual

Vanilla Resonances

spectroscopy:

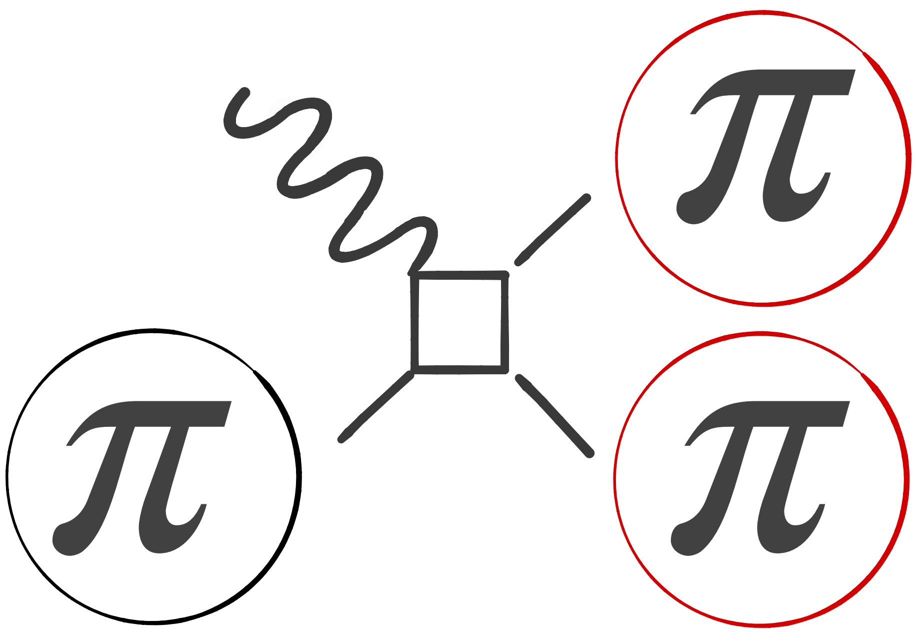
- pole positions
- couplings
- m_π dependence



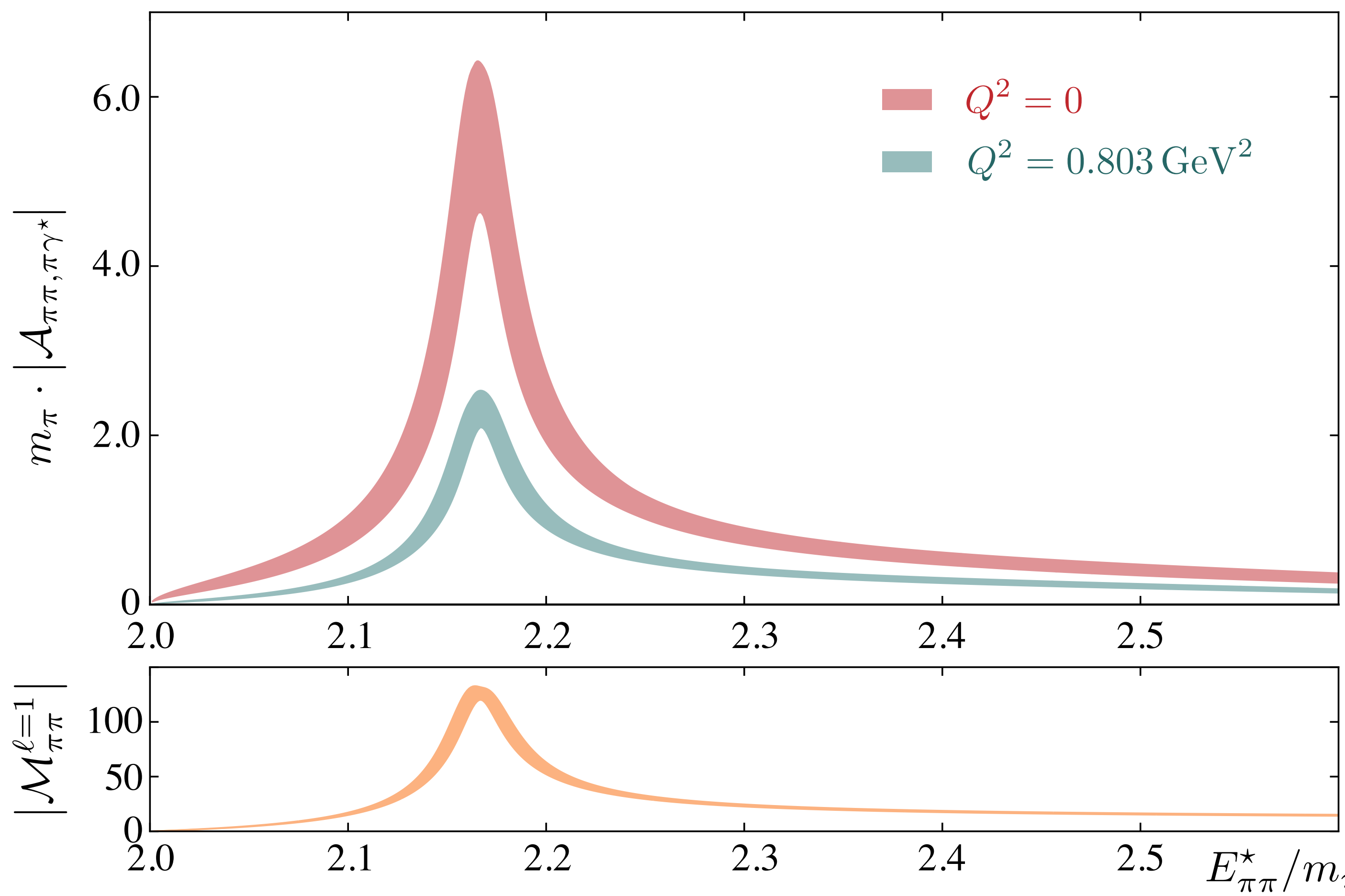


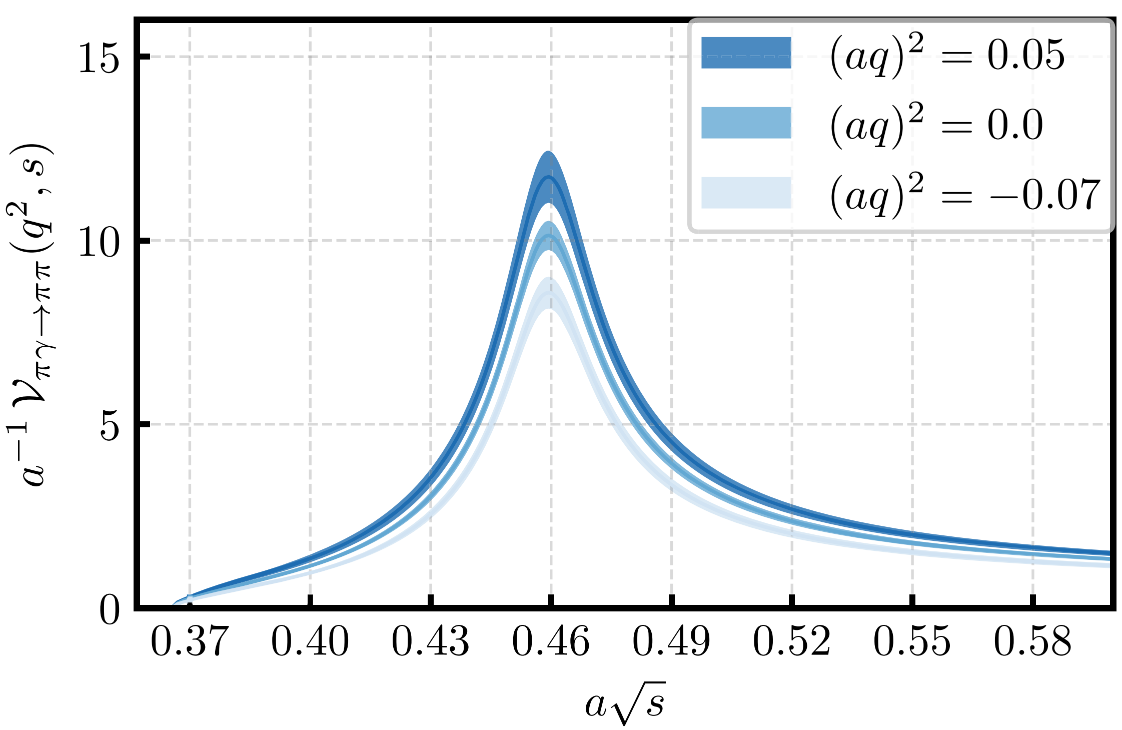
is that enough?

Photo-Production of Resonances



HadSpec, 1507.06622
HadSpec, 1604.03530

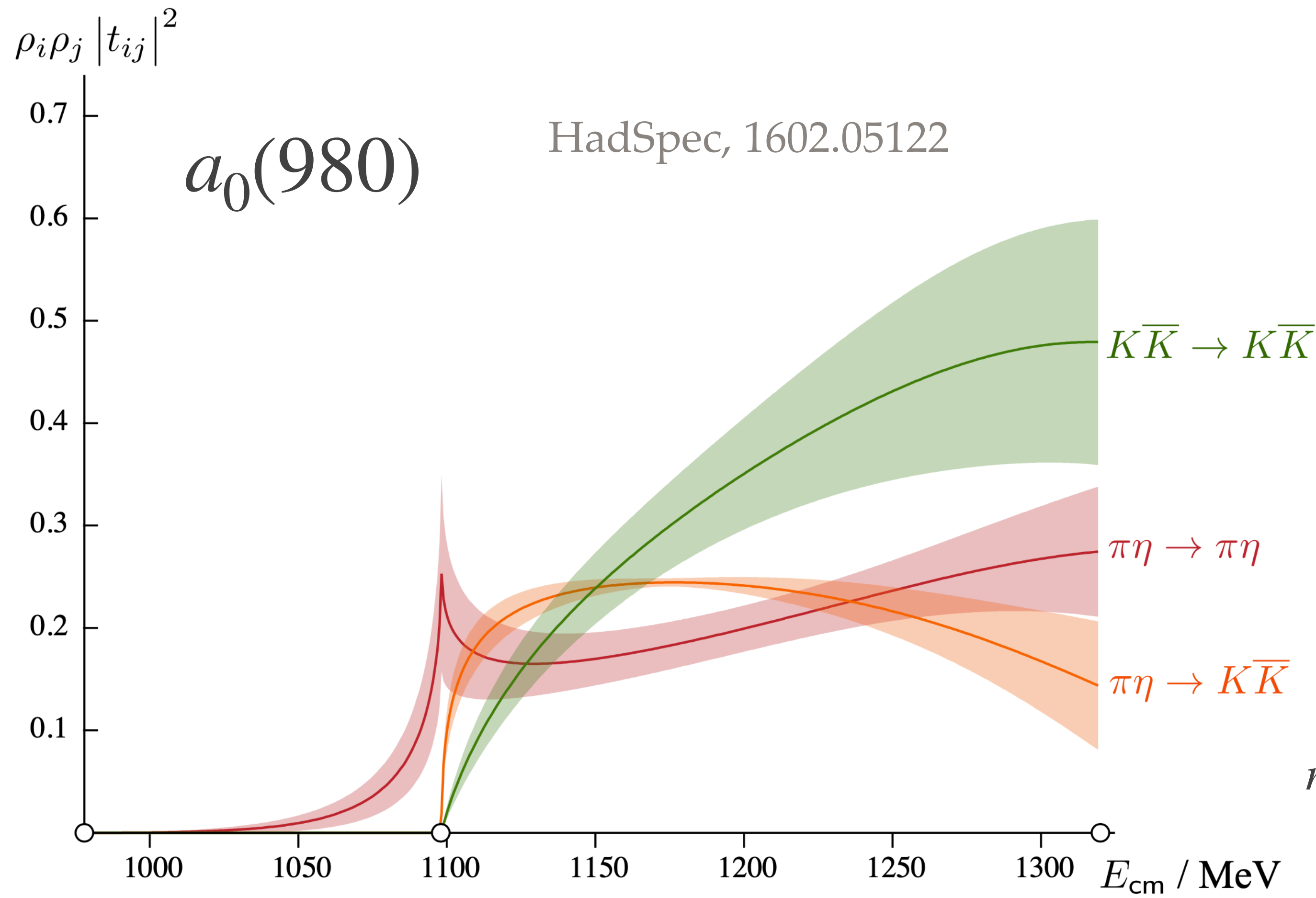


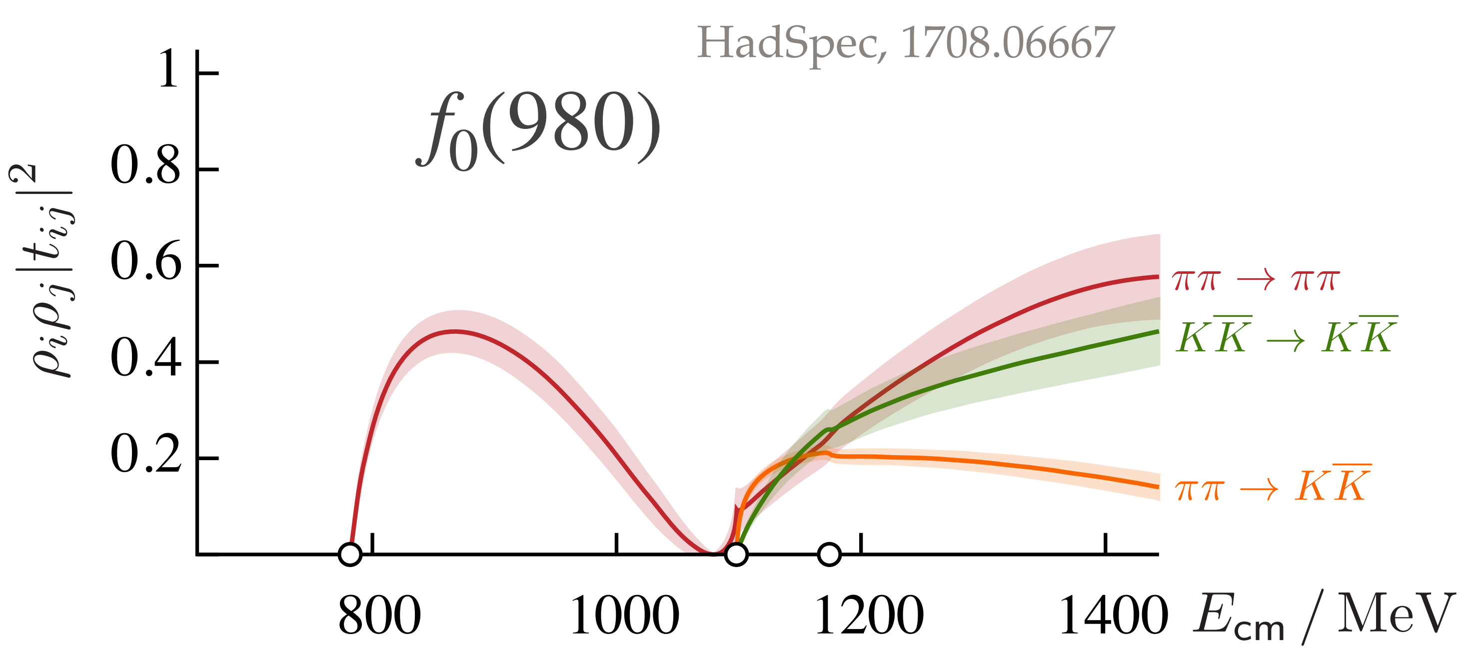


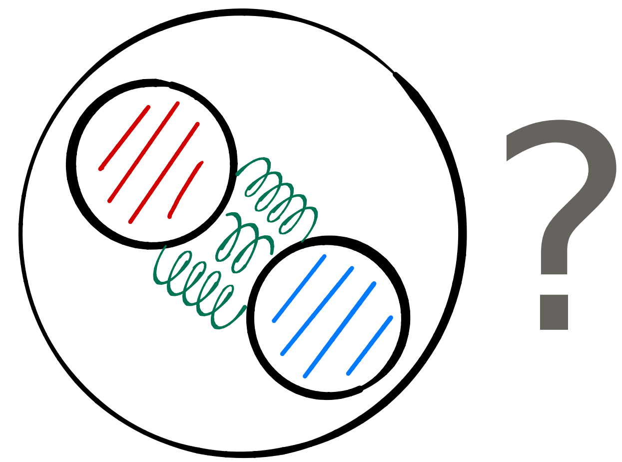
LL et al., 1807.08357

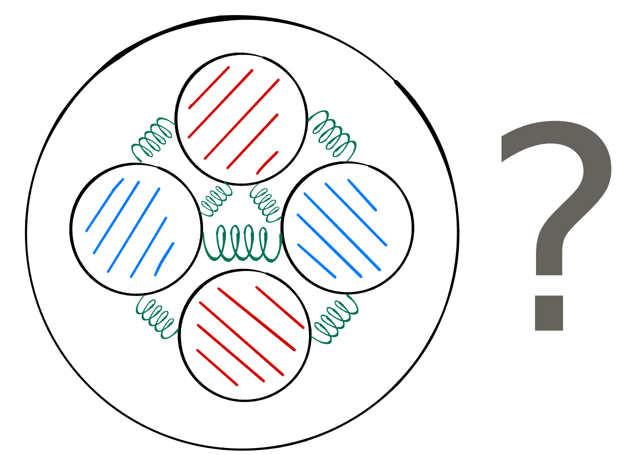
Most Resonances Couple To Multiple Channels

Resonances

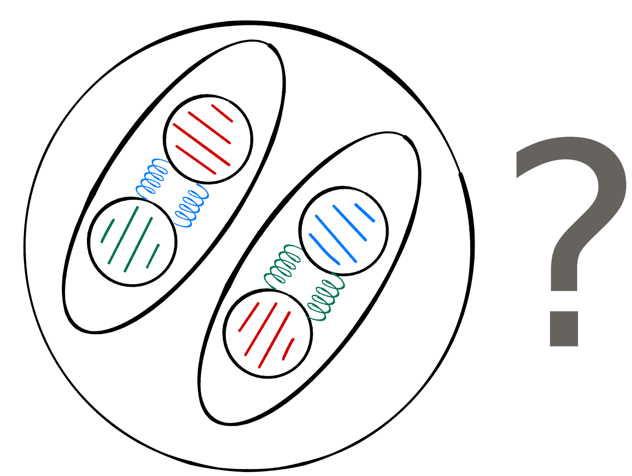








m_π = 390 MeV



Status

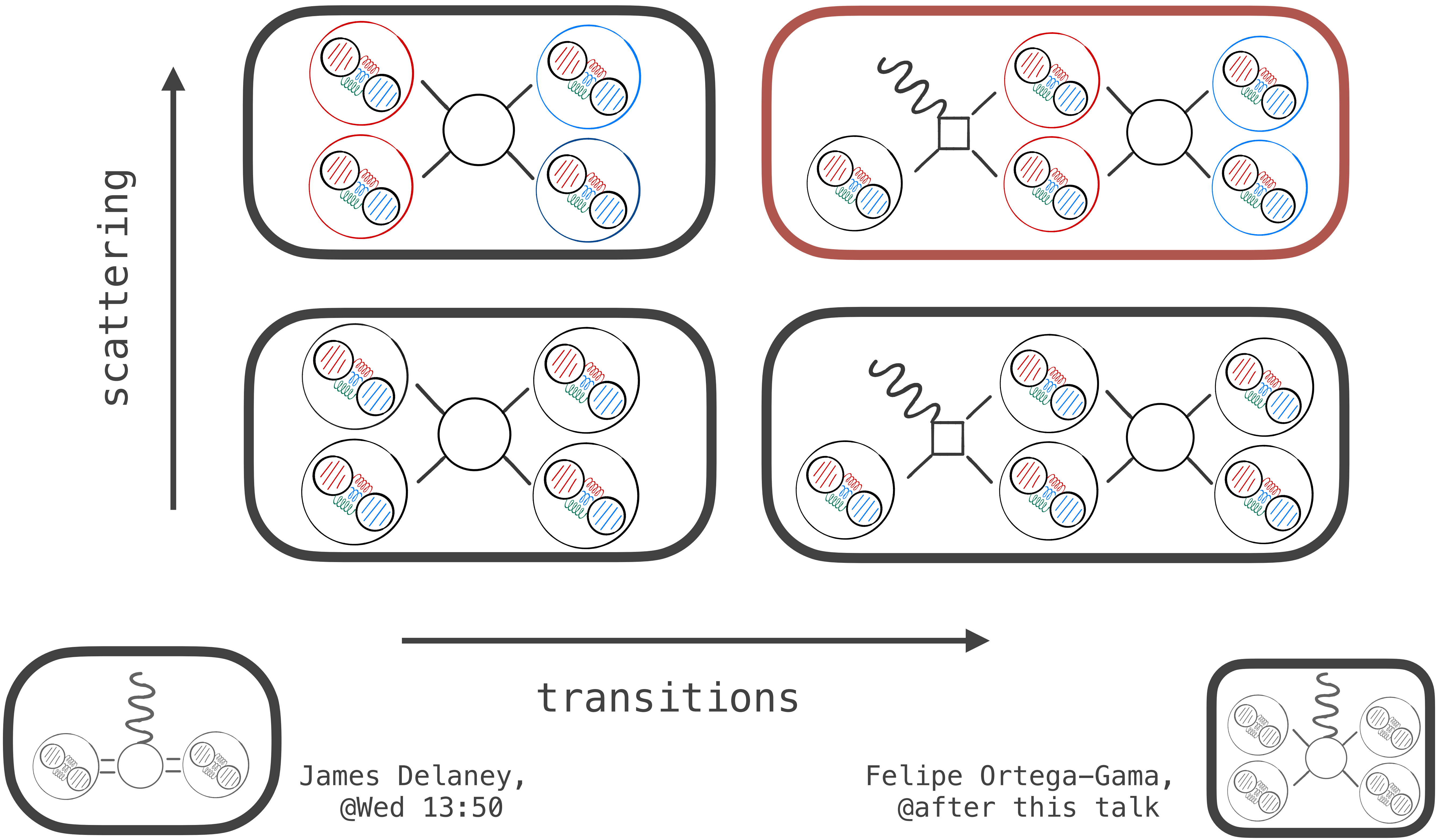
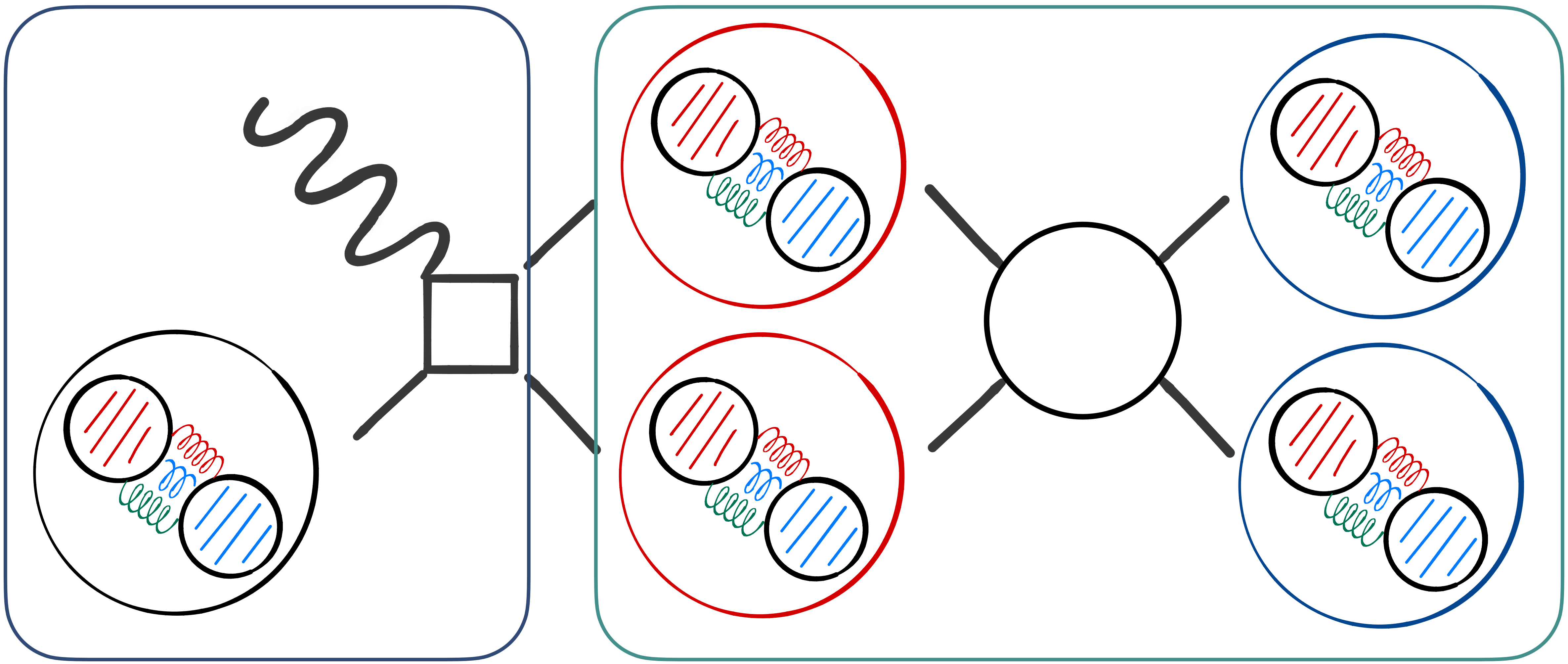

scattering
transitions
James Delaney,
@Wed 13:50
Felipe Ortega-Gama,
@after this talk

Photo-Production: $\gamma^{\star}\chi \to \varphi_1\varphi_1 | \varphi_2\varphi_2$



photoproduction

$\mathscr{A}$

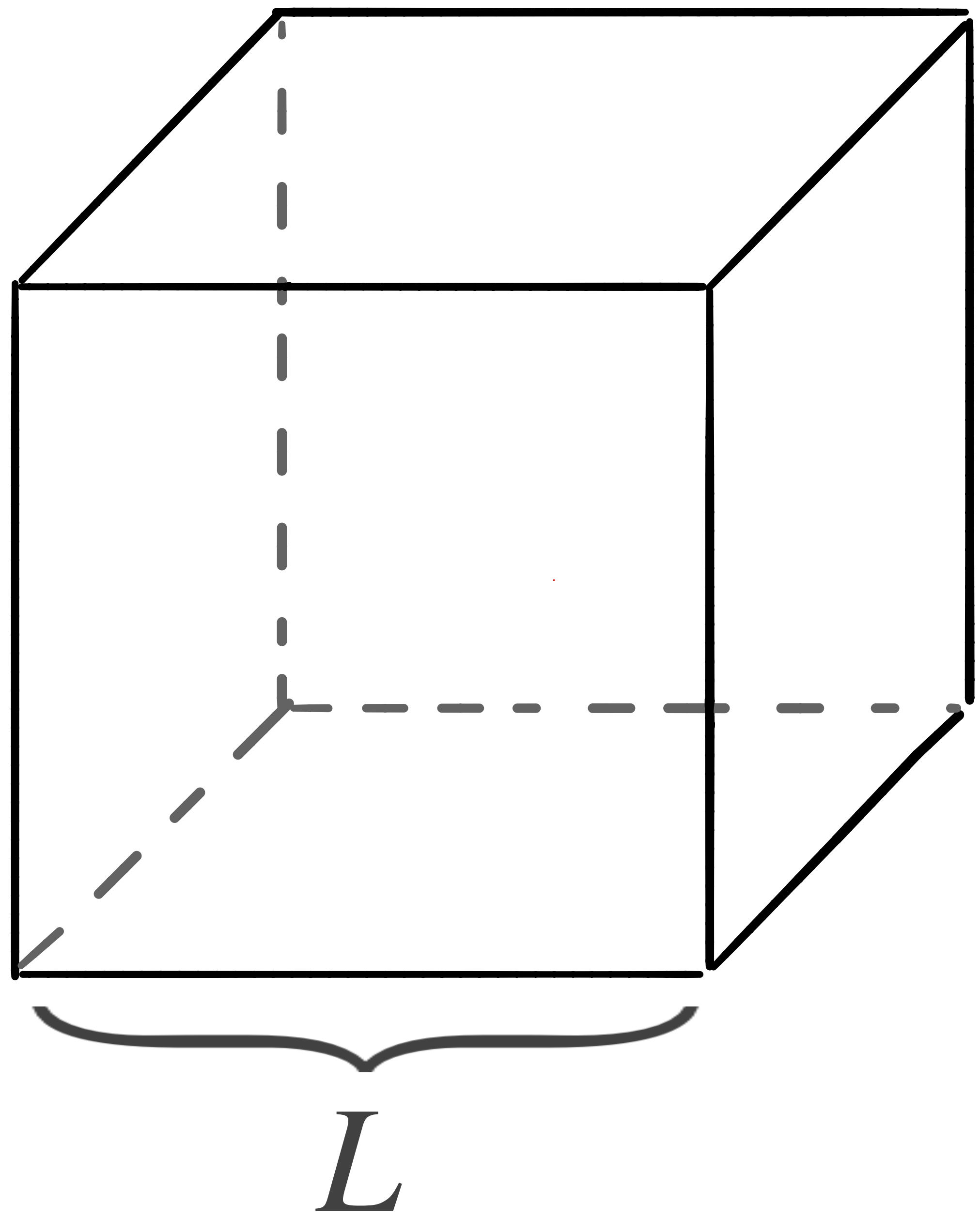
rescattering

$\mathscr{M}$

$$\mathscr{H}(Q^2, E^{\star}) = \mathscr{A}(Q^2, E^{\star}) \cdot \mathscr{M}(E^{\star})$$

Generating Toy-Model Data

lattice QCD is finite volume

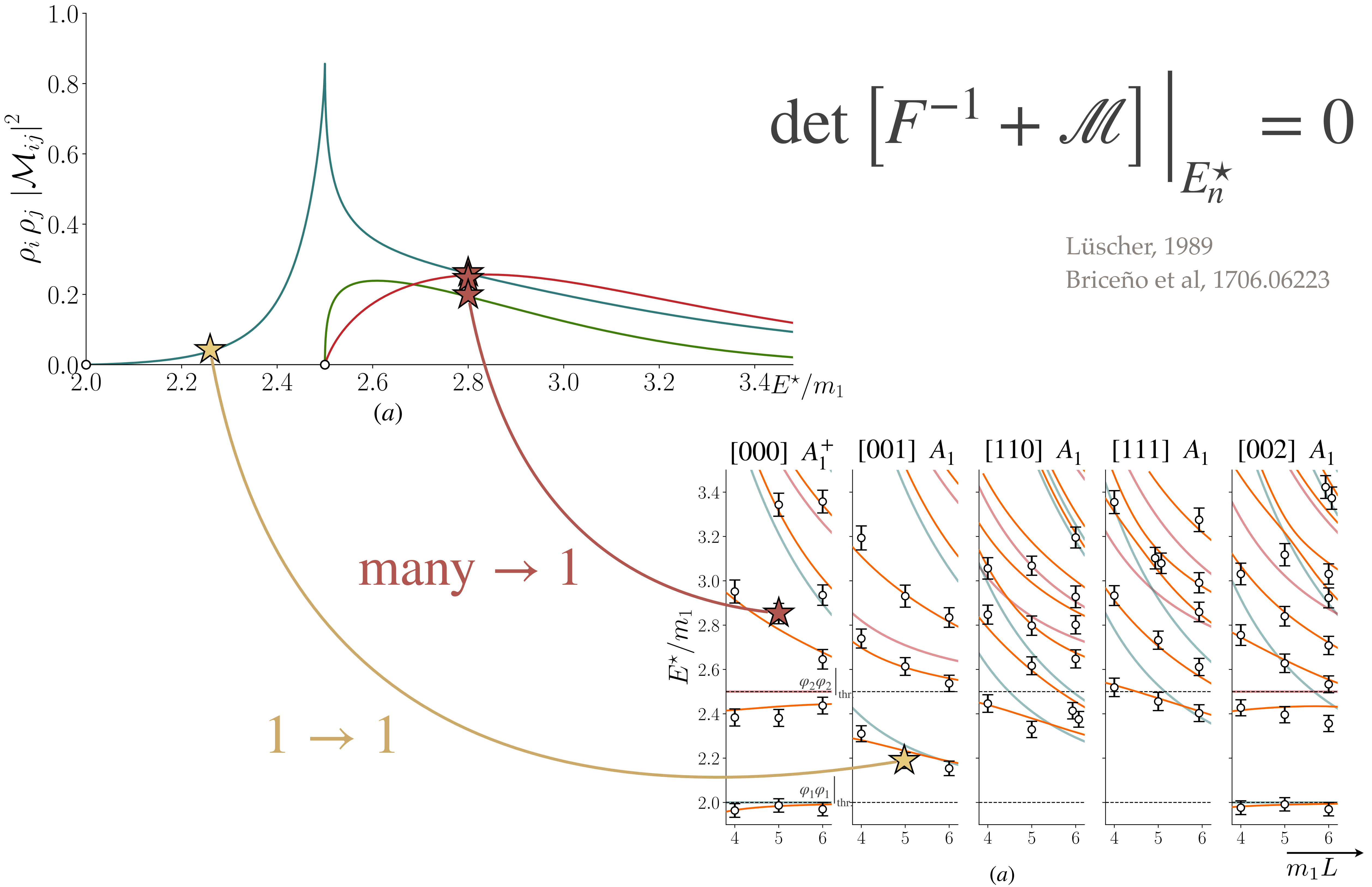


- box
  - side L
  - $\psi(x+L) = \psi(x)$
- discrete spectrum

scattering in finite volume

$$\det\left[F^{-1}+\mathcal{M}\right]\Big|_{E_n^\star}=0$$

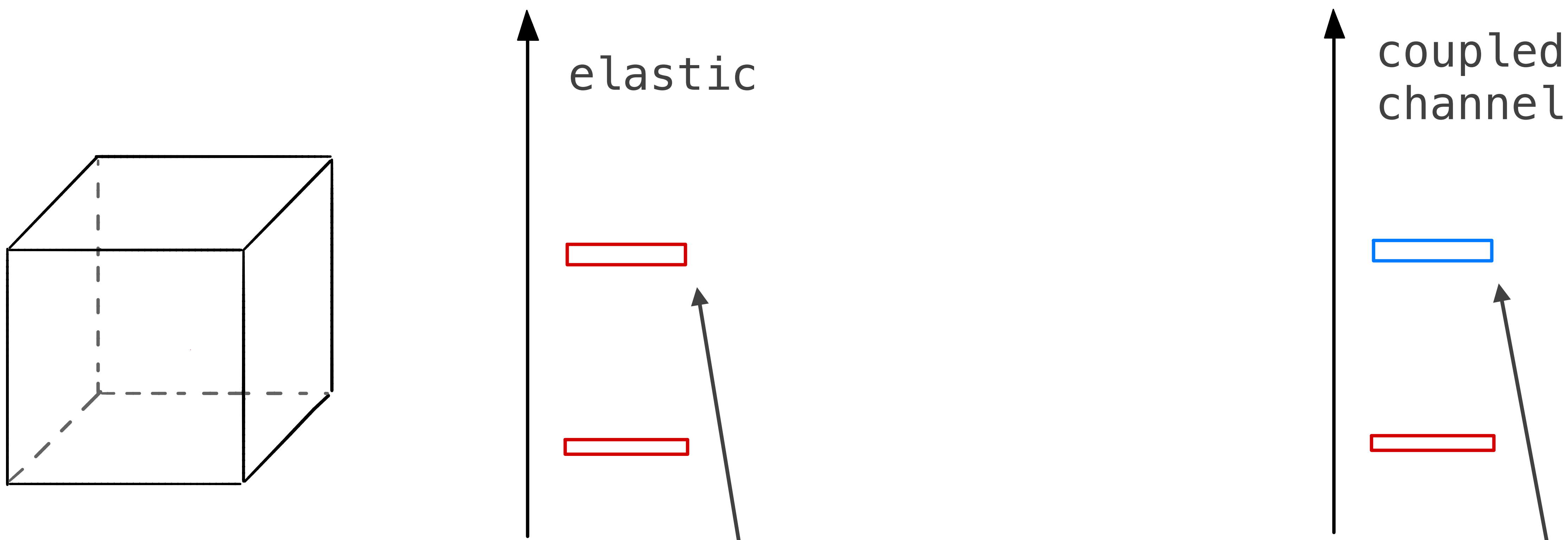
Lüscher, 1989
Briceño et al, 1706.06223



states in finite volume

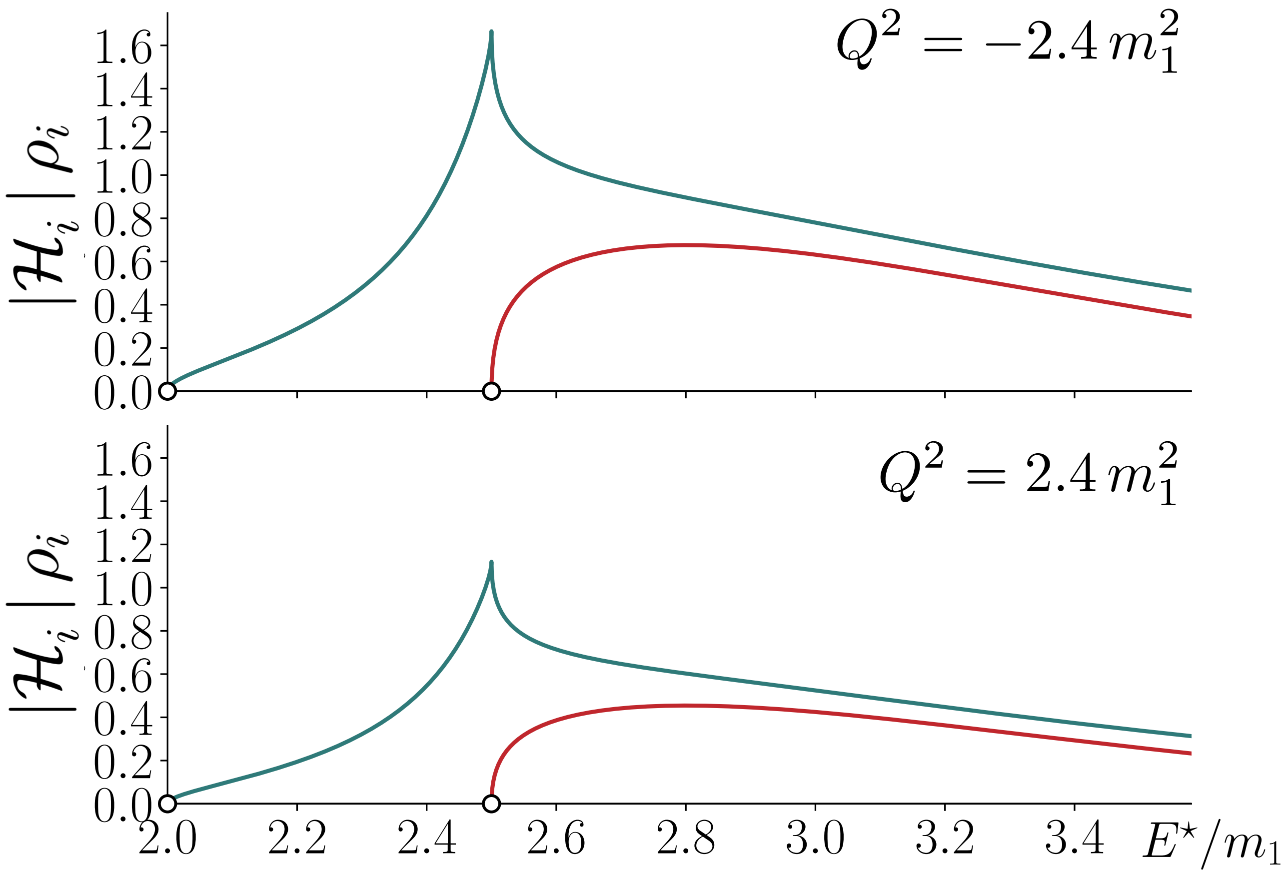
Briceño et al, 1406.5965

$$\mathcal{R}_n = \left.\frac{E - E_n}{F^{-1} + \mathcal{M}}\right|_{E_n^\star} = \left.\frac{1}{\lambda_0'}\mathbf{v}_0\mathbf{v}_0^T\right|_{E_n^\star}$$

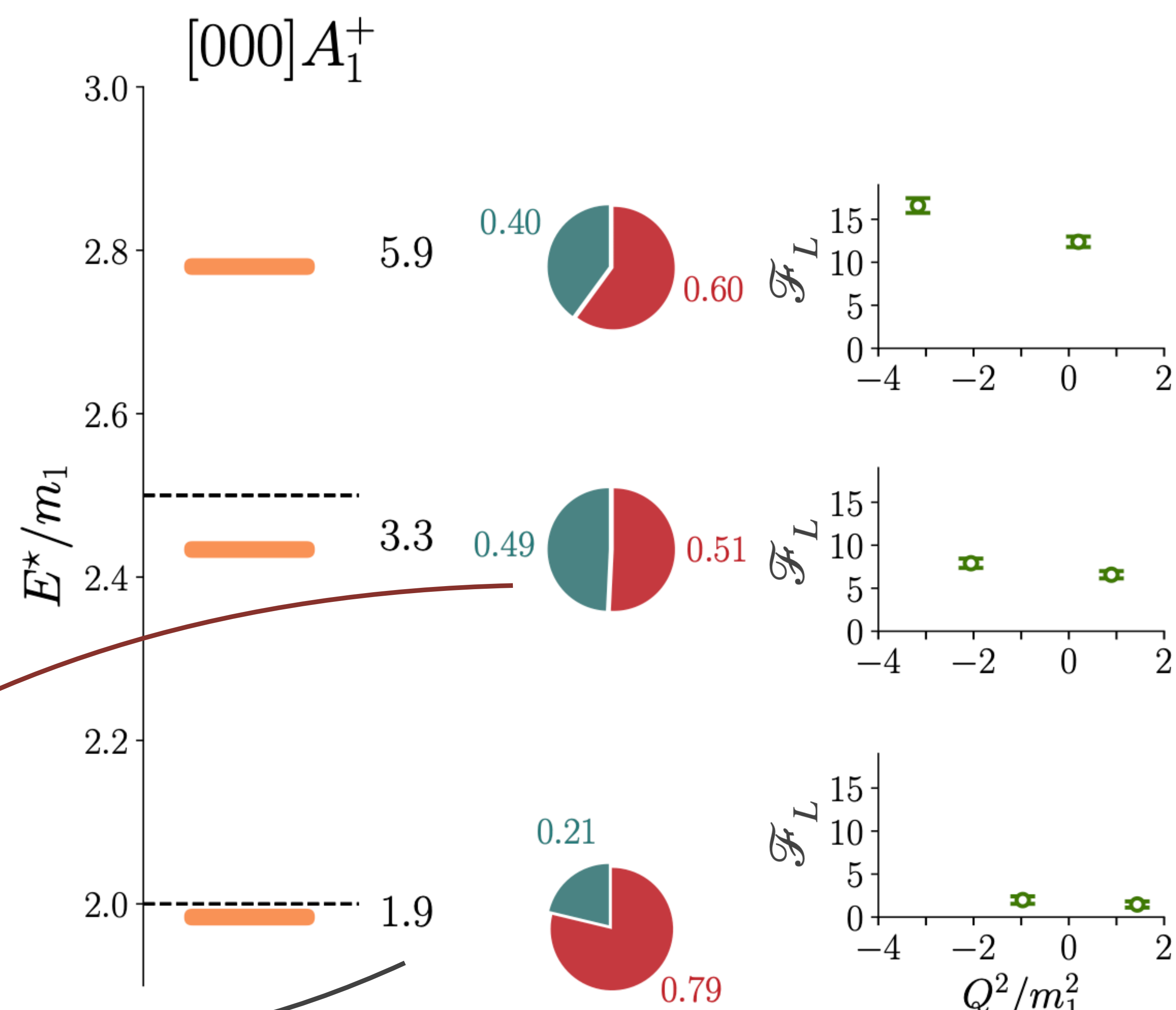


normalization: $|E_n\rangle_L \sim \sqrt{\mathcal{R}_n}\,|\varphi\varphi(E^\star = E_n^\star)\rangle_\infty$ $\quad |E_n\rangle_L \sim \sqrt{\frac{1}{\lambda_0'}}(\mathbf{v}_0)_a\,|\varphi_a\varphi_a(E^\star = E_n^\star)\rangle_\infty$

transitions in finite volume



$$\left[F+\mathcal{M}^{-1}\right]\Big|_{E_n^\star} = \sum_i \mu_i \mathbf{w}_i \mathbf{w}_i^T$$

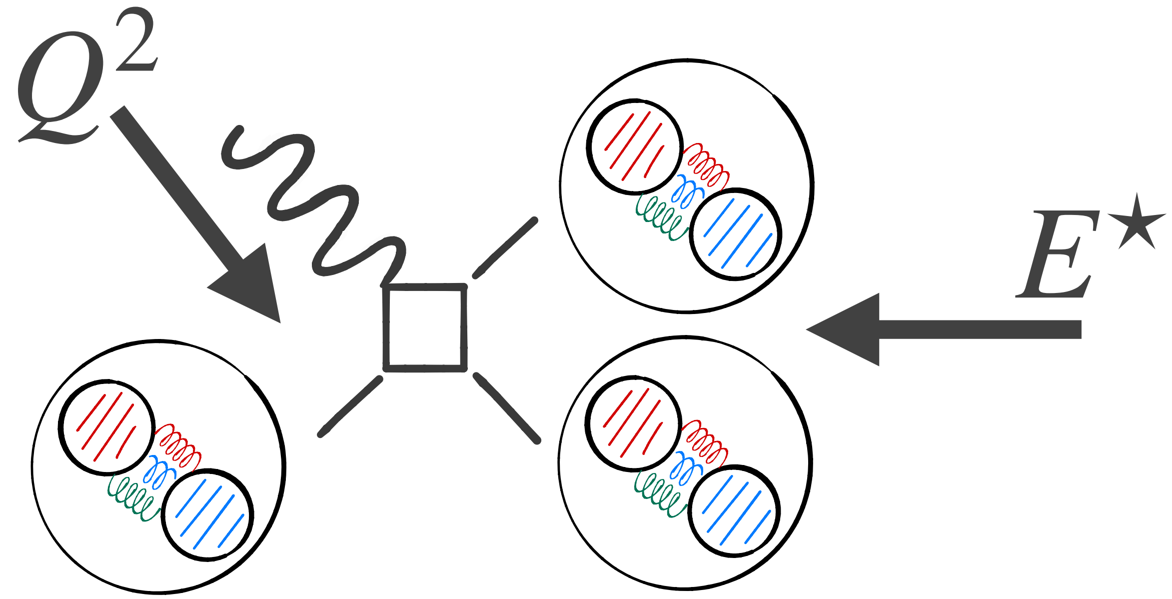


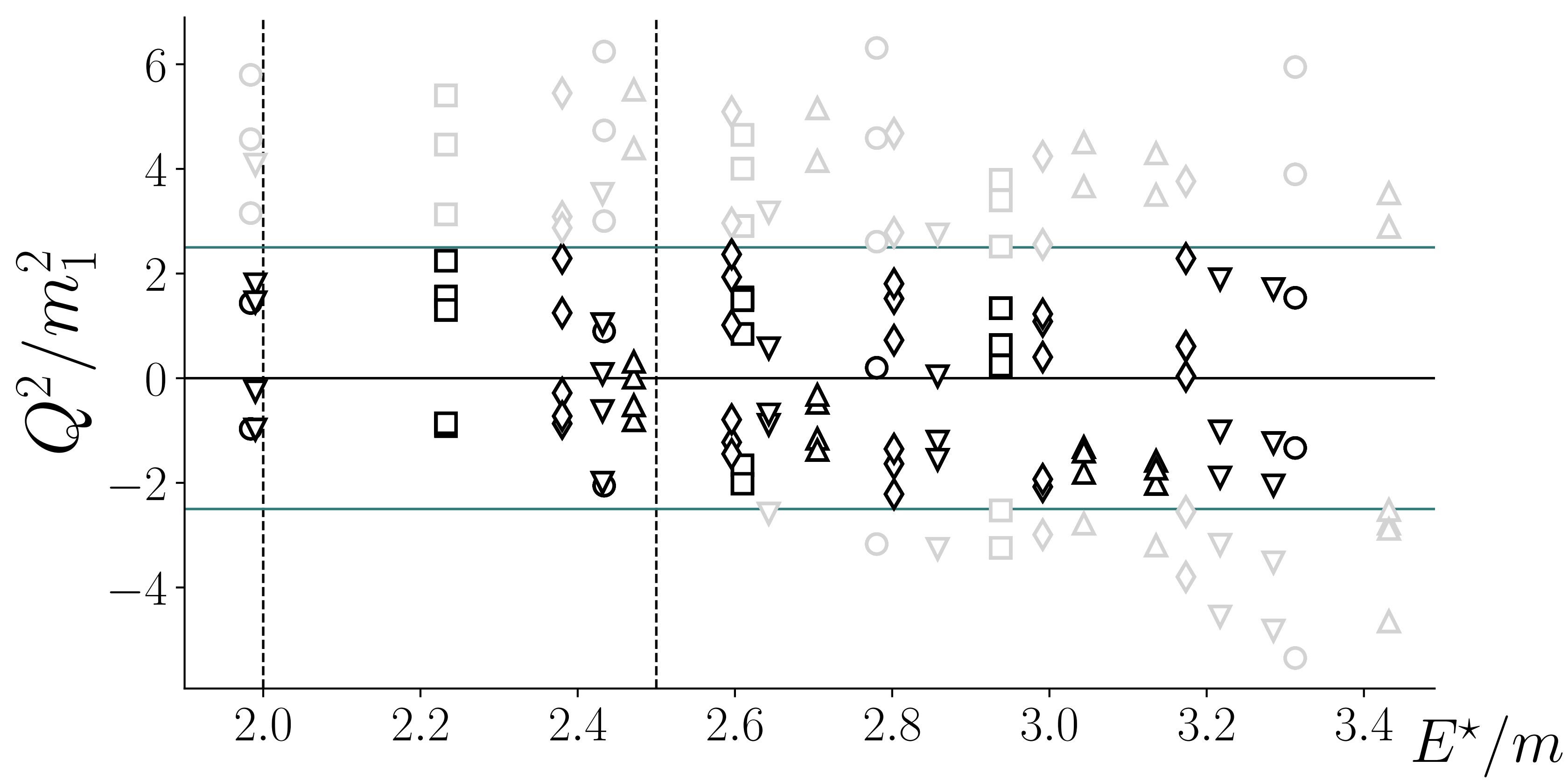
$$\mathcal{H} = \mathcal{A}\cdot\mathcal{M}$$

$$|\mathcal{F}_L| = \frac{1}{L^3\sqrt{2E_i}}\sqrt{\frac{1}{-\mu_0'}}\,\mathbf{w}_0^T\cdot\mathcal{A}$$

synthetic data

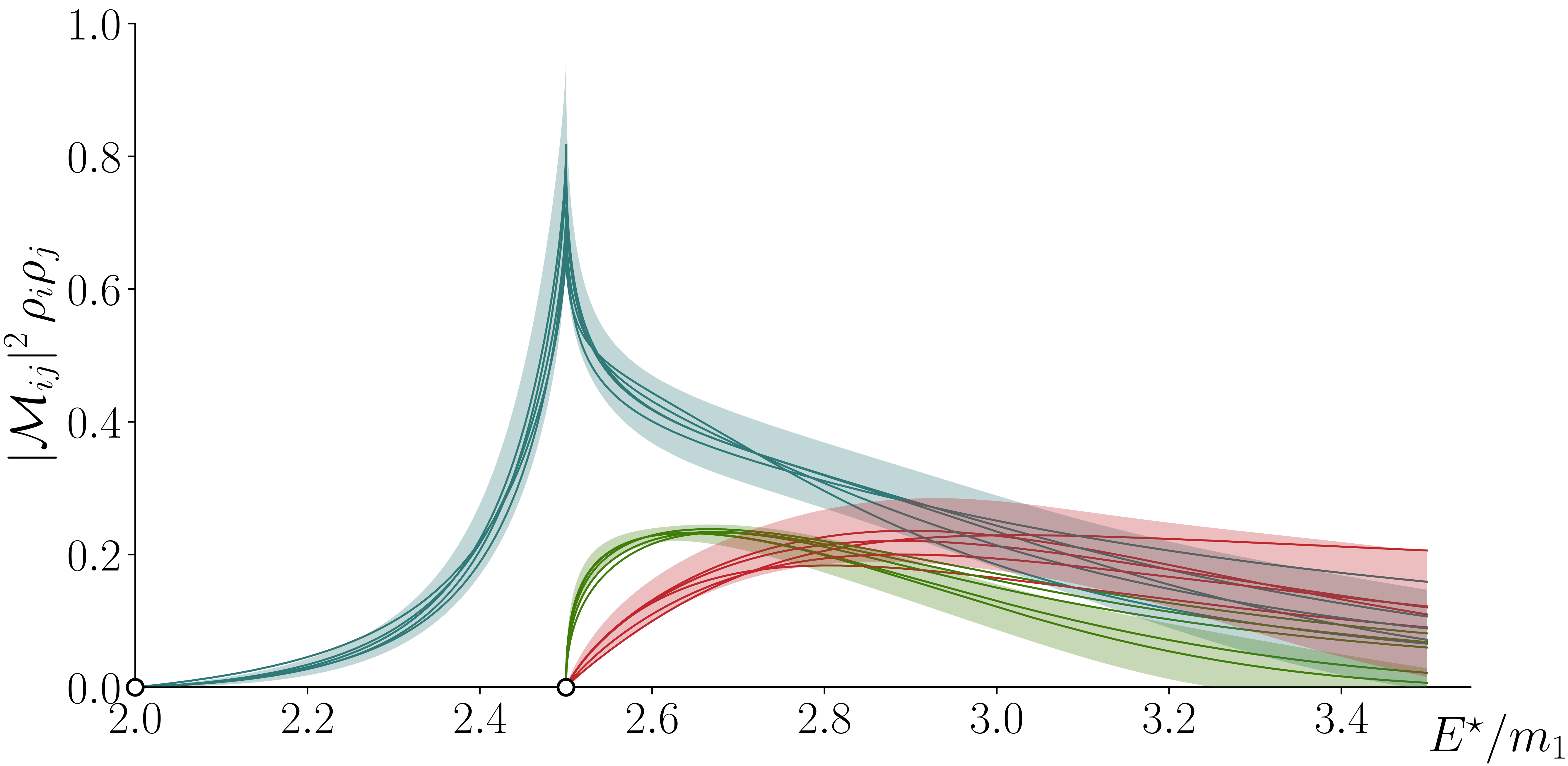
- spectrum
  - discrete E_n
  - 5 frames
  - $(m_1 L = 5)$
- transition
  - (Q^2, E_n)
  - $\mathcal{F}_L$



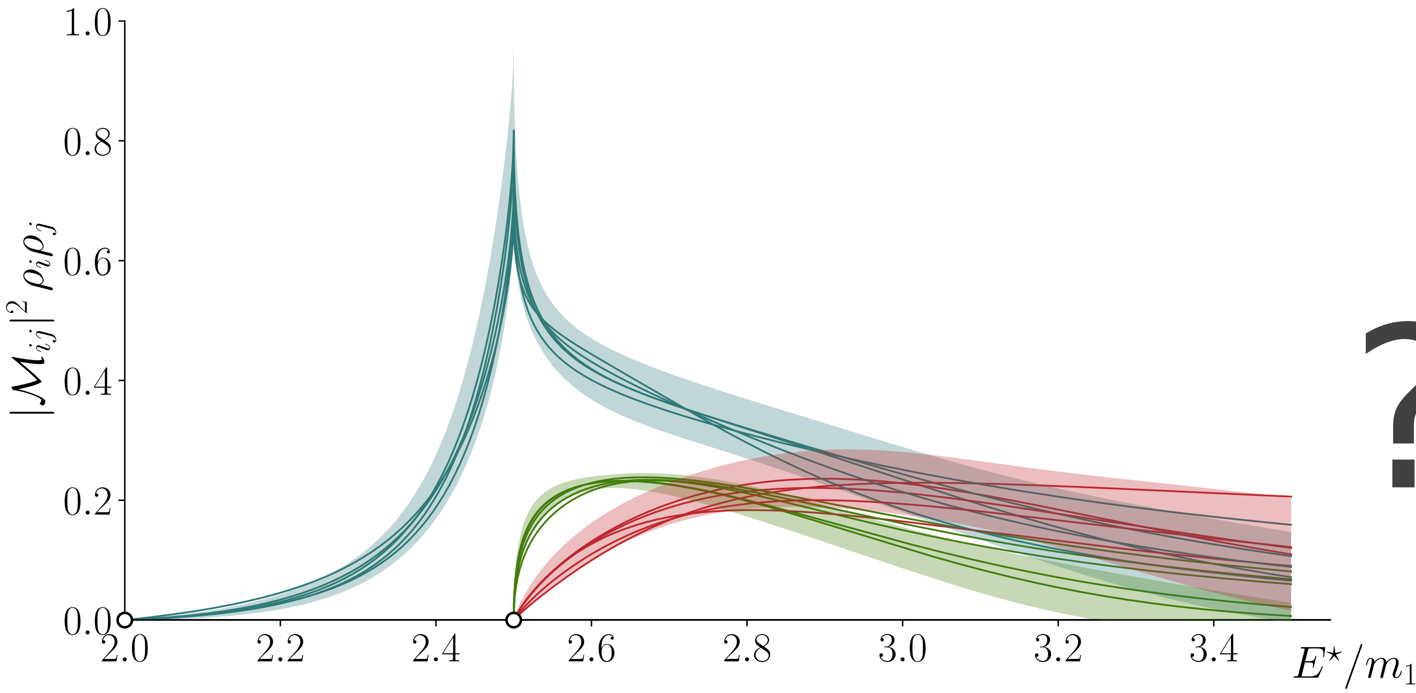


Analyzing The Data

can we reproduce $\mathscr{M}$?



How To Define A Resonance?



?

- peak position?
- half-max width?

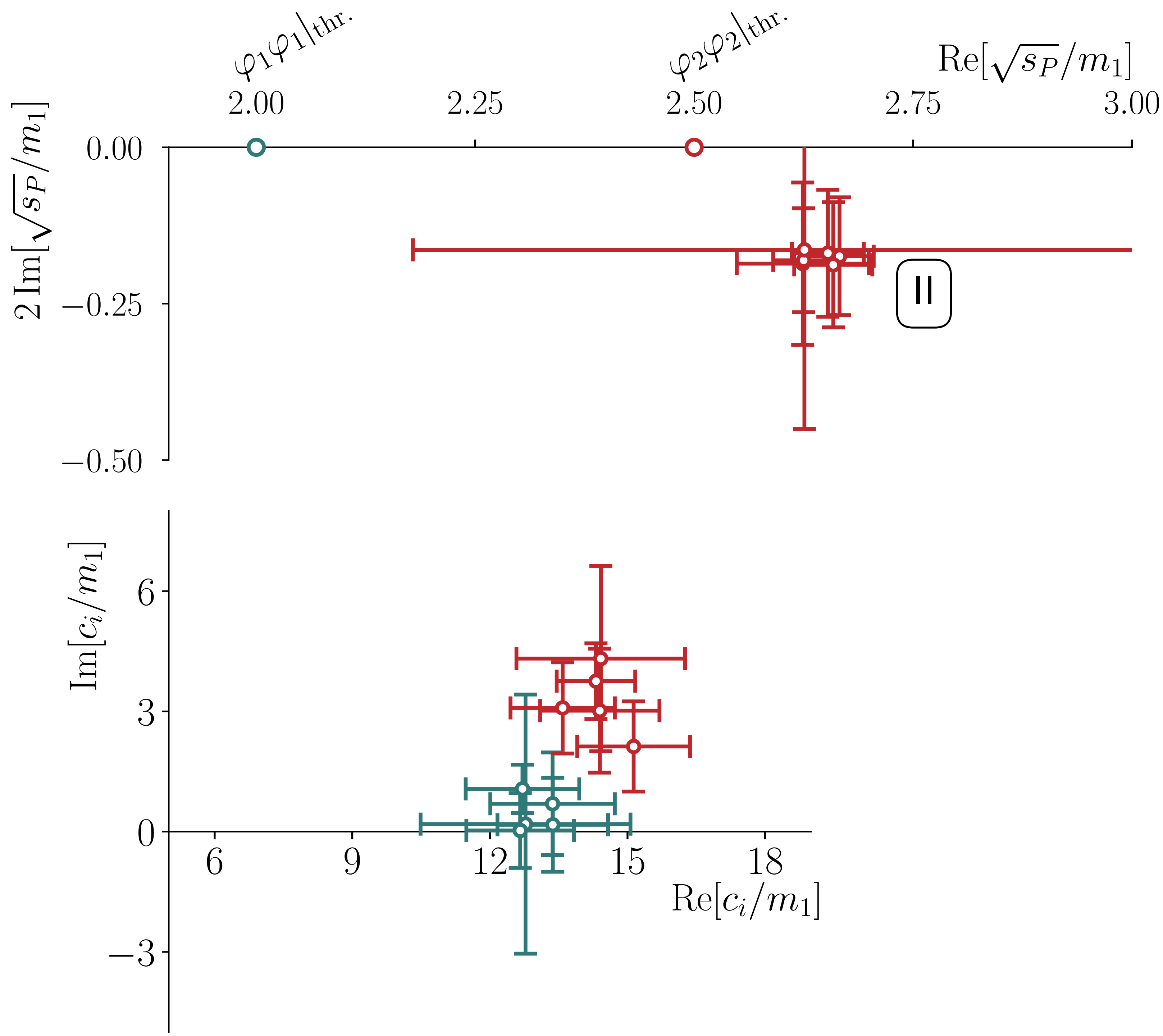
1. analytically continue $\mathscr{M}$ to pole
2. decompose as

$$\mathscr{M}_{ij} \approx \frac{c_i\, c_j}{s_P - s}$$

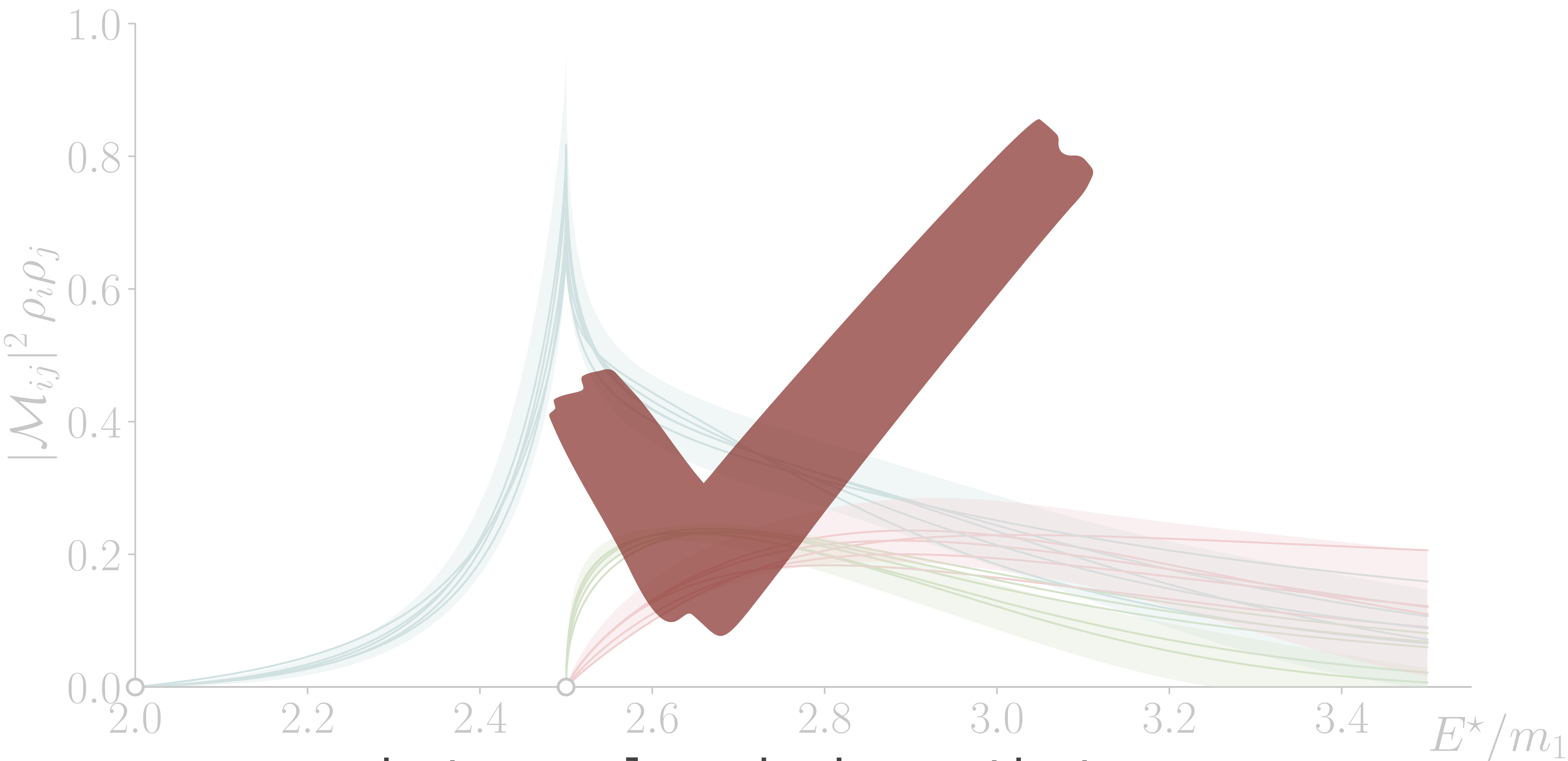
3. pole and residues/couplings!

can we reproduce $\mathscr{M}$?

$$\mathscr{M}_{ij} \approx \frac{c_i\, c_j}{s_P - s}$$



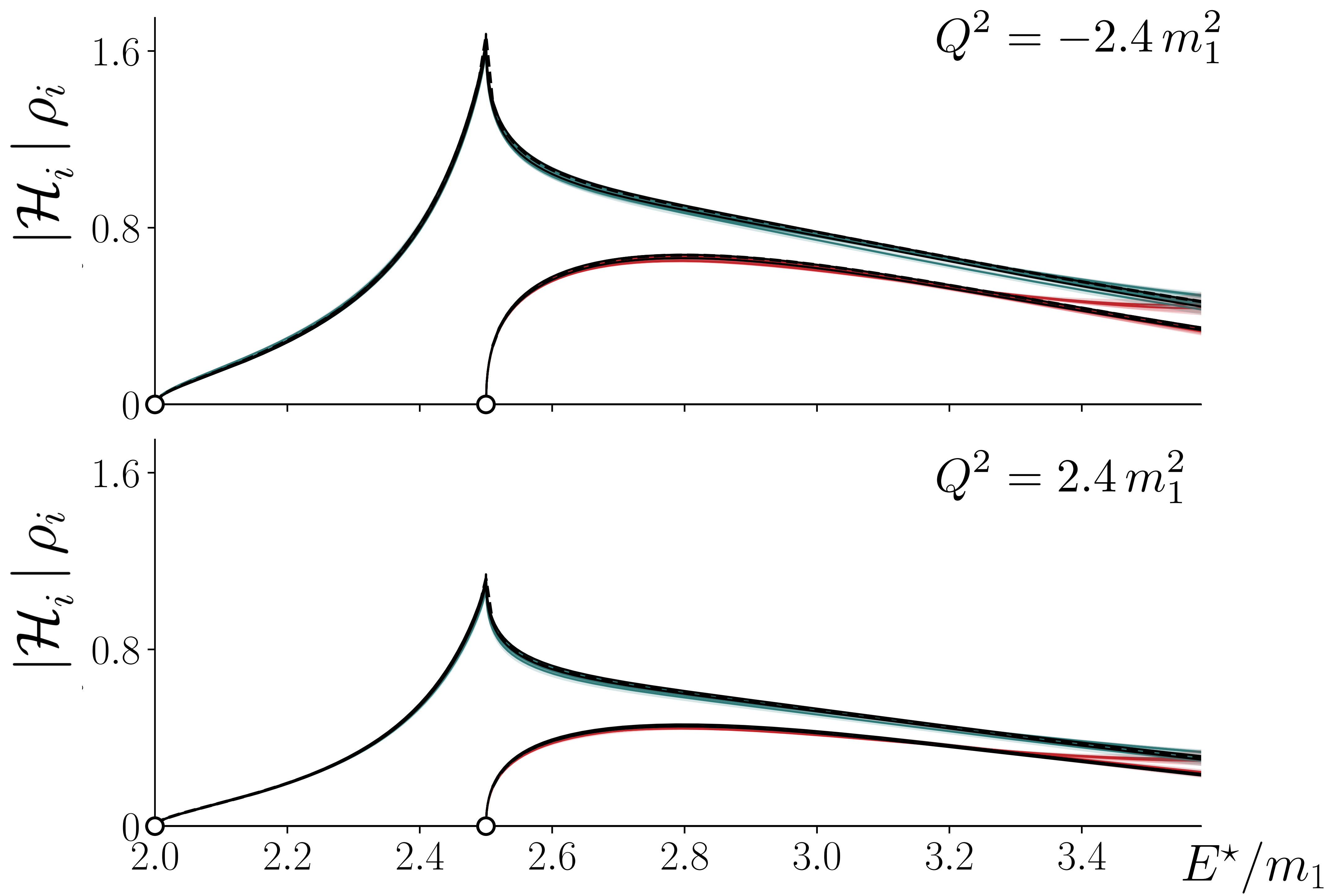
can we reproduce $\mathscr{M}$?



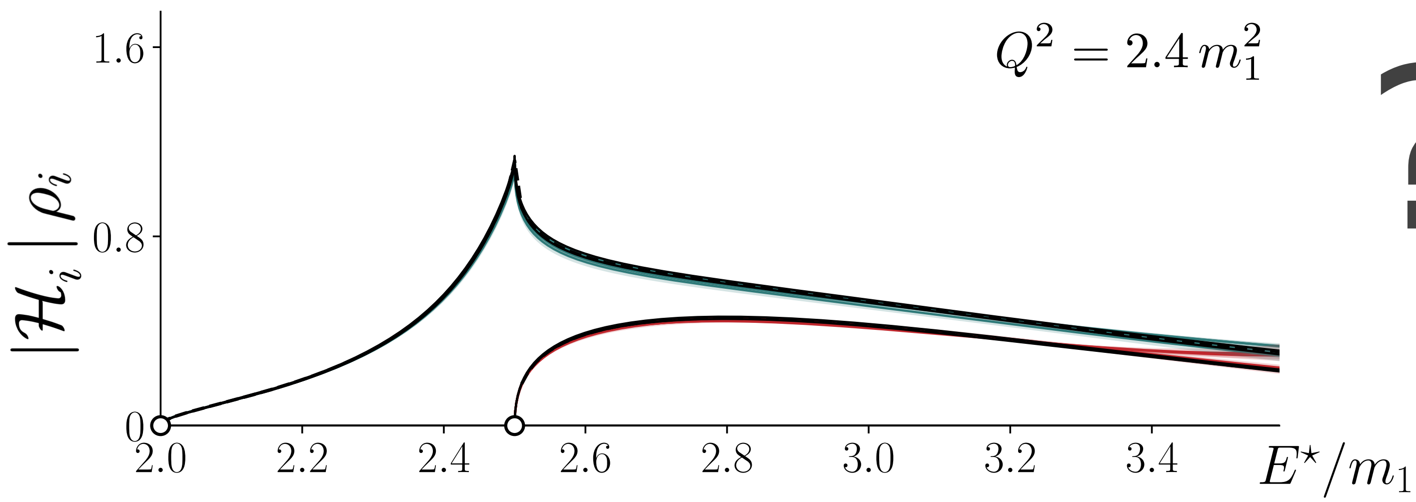
but we already knew that

Guo et al., 1211.0929

can we reproduce $\mathscr{H}$?



What Is A Form Factor Of A Resonance?



?

- peak position?
- fit a Breit-Wigner?

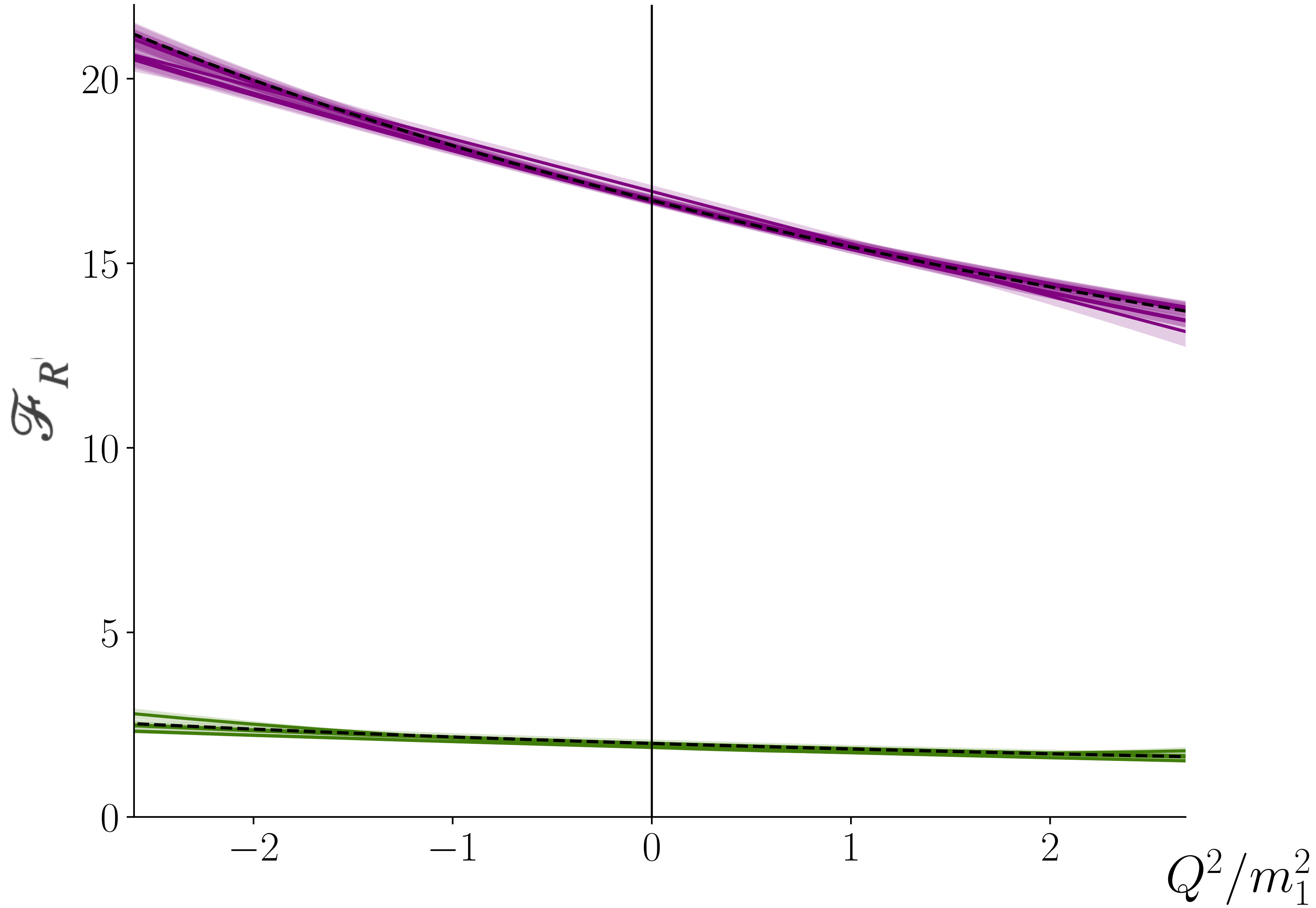
1. analytically continue $\mathscr{H}_i$ to pole
2. decompose as

$$\mathscr{H}_i \approx \frac{c_i\,\mathscr{F}_R(Q^2)}{s_P - s}$$

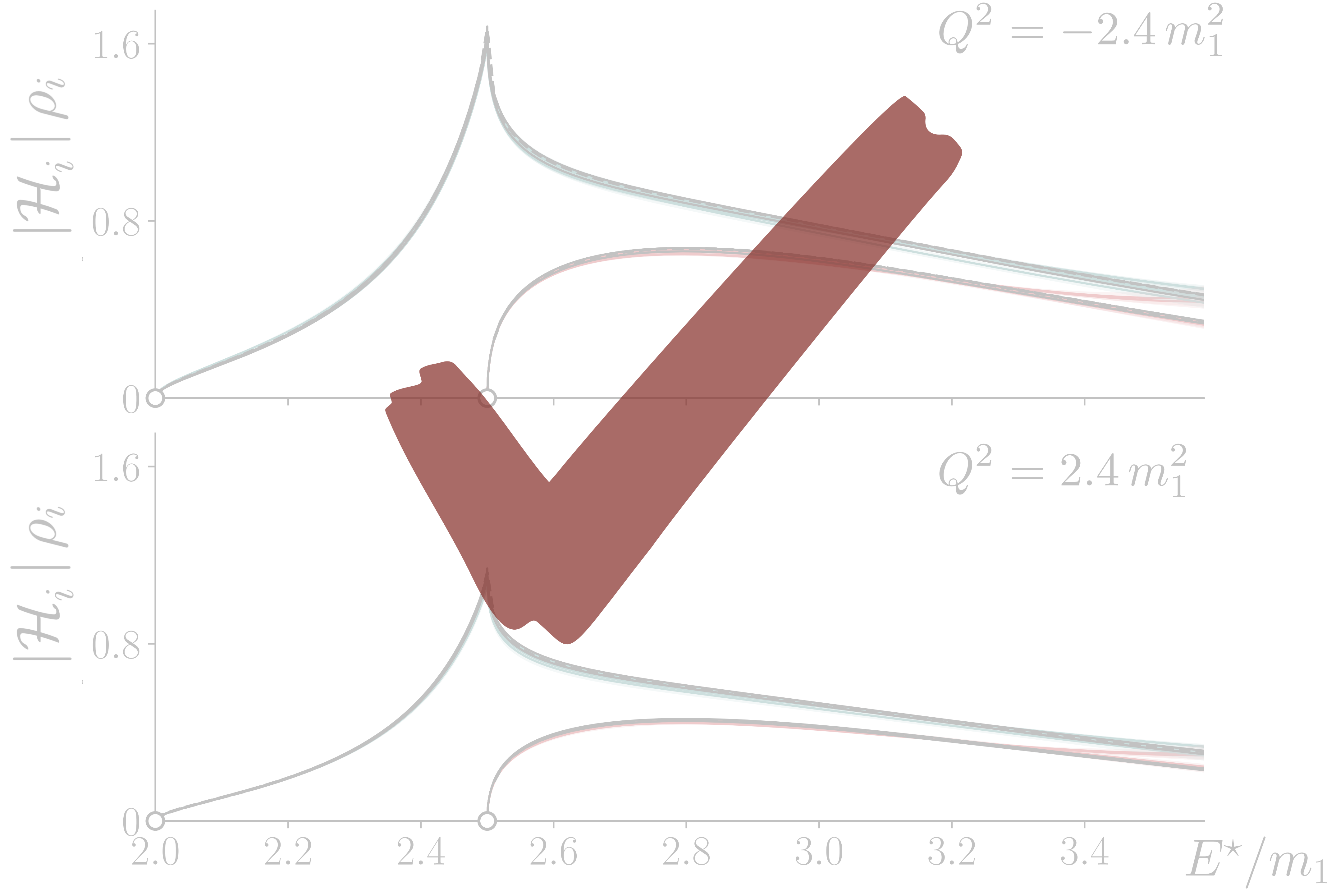
3. coupling at pole at different Q^2

can we reproduce $\mathscr{H}$?

$$\mathscr{H}_i \approx \frac{c_i \mathscr{F}_R(Q^2)}{s_P - s}$$



can we reproduce $\mathscr{H}$?



Summary

- toy model spectrum + transitions
- finite volume
- analysis reproduces input
- now we can do lattice QCD calculations
- insight into hadrons